

# Geostationary Coastal & Air Pollution Events



## Synthesis of Coastal Ecosystem Science Studies on Sensitivity and Spatial Resolution for GEO-CAPE

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### **Acknowledgments**

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# Outline

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- Background on GEO-CAPE Mission with focus on coastal waters
  - Science questions
  - Approach
  - Field of Regard
- Studies that inform on sensitivity and SNR issues for GEO-CAPE
  - Ltyp determination
  - SNR for heritage sensors
- Study on atmospheric corrections
- Studies that inform on spatial resolution requirements for GEO-CAPE
  - Spatial dynamics of an algal bloom
  - Spatial dispersion of suspended particles
  - Tidal exchanges across the land-ocean interface: time and space scales
- Synergies between PACE and GEO-CAPE

# Background

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- Mission provides high temporal, spatial, and spectral resolution observations that will resolve the diurnal evolution of North and South America
  - Coastal ocean ecology, biogeochemistry, water quality, event scale and sub-mesoscale biological/biogeochemical processes.
  - atmospheric composition (descoped to only North America)



# Background

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- Mission provides high temporal, spatial, and spectral resolution observations that will **resolve the diurnal evolution** of North and South America
  - coastal ocean ecology, water quality, event scale process & understanding, and sub-mesoscale biological/biogeochemical processes.
  - atmospheric composition (descoped to only North America)
- Multiple Instruments (TBD) – **selection by open competition**
  - UV-VIS-NIR hyperspectral sensor plus SWIR bands with high spatial resolution (250 to 500 m) – Ocean Color
  - UV-VIS hyperspectral sensor with coarser resolution (2 to 7 km) for atmospheric trace gas composition and aerosols
  - IR gas correlation sensor (for CO)
  - Thermal Infrared sensor

Pre-phase A formulation (science & engineering studies)

*<http://geo-cape.larc.nasa.gov>*

# **GEO-CAPE Ocean Science Questions**

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## **Short-Term Processes**

1. How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics?

## **Land-Ocean Exchange**

2. How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics?

## **Impacts of Climate Change & Human Activity**

- How are the **productivity and biodiversity of coastal ecosystems** changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability?

## **Impacts of Airborne-Derived Fluxes**

- How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes significantly affect the ecology and biogeochemistry of coastal and open ocean ecosystems?

## **Episodic Events & Hazards**

- How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone?

# Approach

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GEO-CAPE will observe coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, and track carbon pools and pollutants.

Two operational modes:

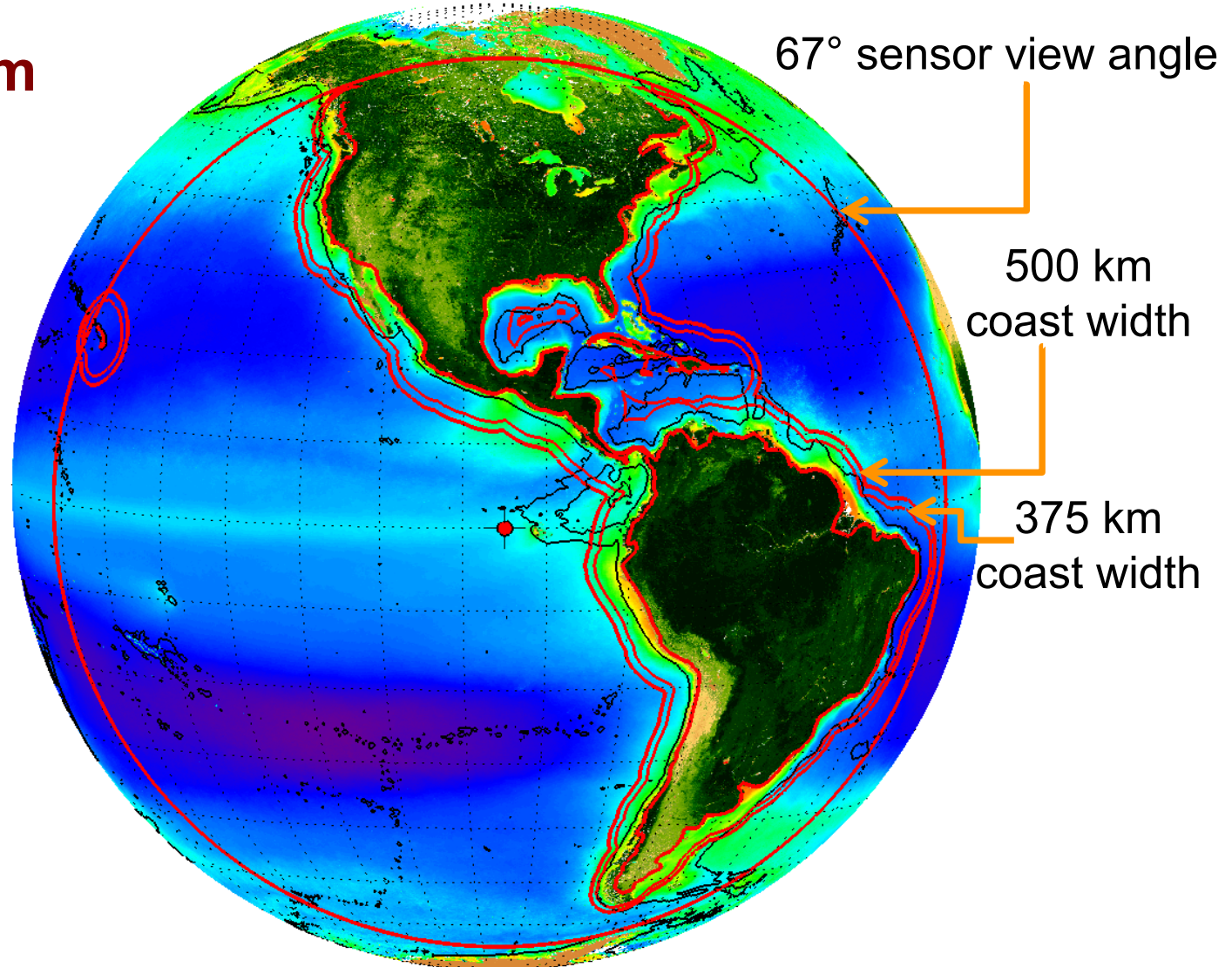
1. **survey mode** for evaluation of diurnal to interannual variability of constituents, rate measurements and hazards ...

- U.S. coastal waters
- Regions of special interest
- All other coastal waters from  $\sim 60^{\circ}\text{N}$  to  $60^{\circ}\text{S}$

2. **targeted, high-frequency sampling** for observing episodic events (and support for coastal and deep ocean cruises) ...

## Geostationary view from 95°W

**~36,000 km  
altitude**



- Within  $AMF \leq 5$ , where atmospheric correction is feasible, coverage extends to  $\sim 60^\circ$  latitude in summer and  $\sim 50^\circ$  in winter and from  $\sim 30^\circ W$  to  $\sim 155^\circ W$  (at equator).



D. Aurin & A. Mannino

# GEO vs LEO - SNR

## Integration time is key factor!

GEO – stare to >SNR = long integration times (GOCI integrates for 3-6 sec per band)

LEO – much shorter integration times (>10,000 times shorter)

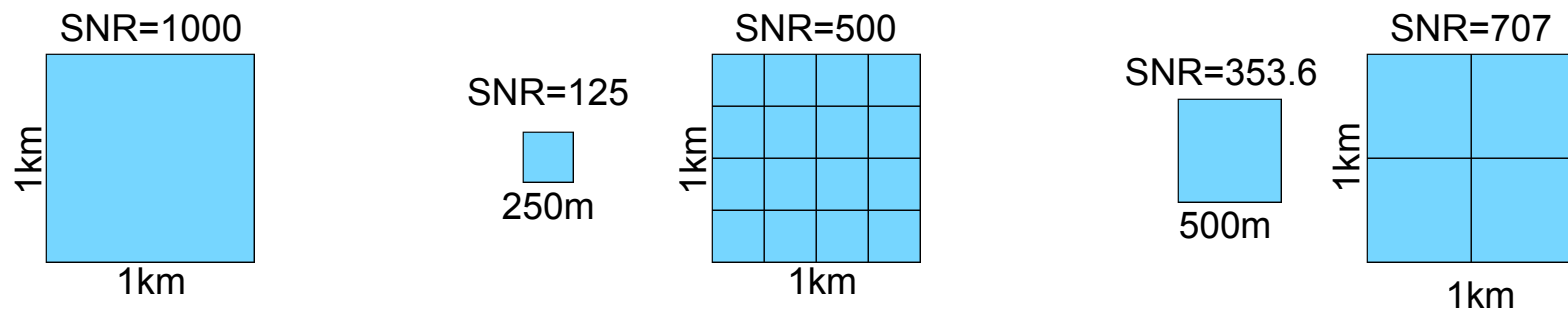
Sample time MODIS 1km bands: 333  $\mu$ sec (323  $\mu$ sec integration time)

Sample time MODIS 500m bands: 167  $\mu$ sec (157  $\mu$ sec integration time)

Sample time MODIS 250m bands: 83  $\mu$ sec (73  $\mu$ sec integration time)

*Source: Robert Wolfe*

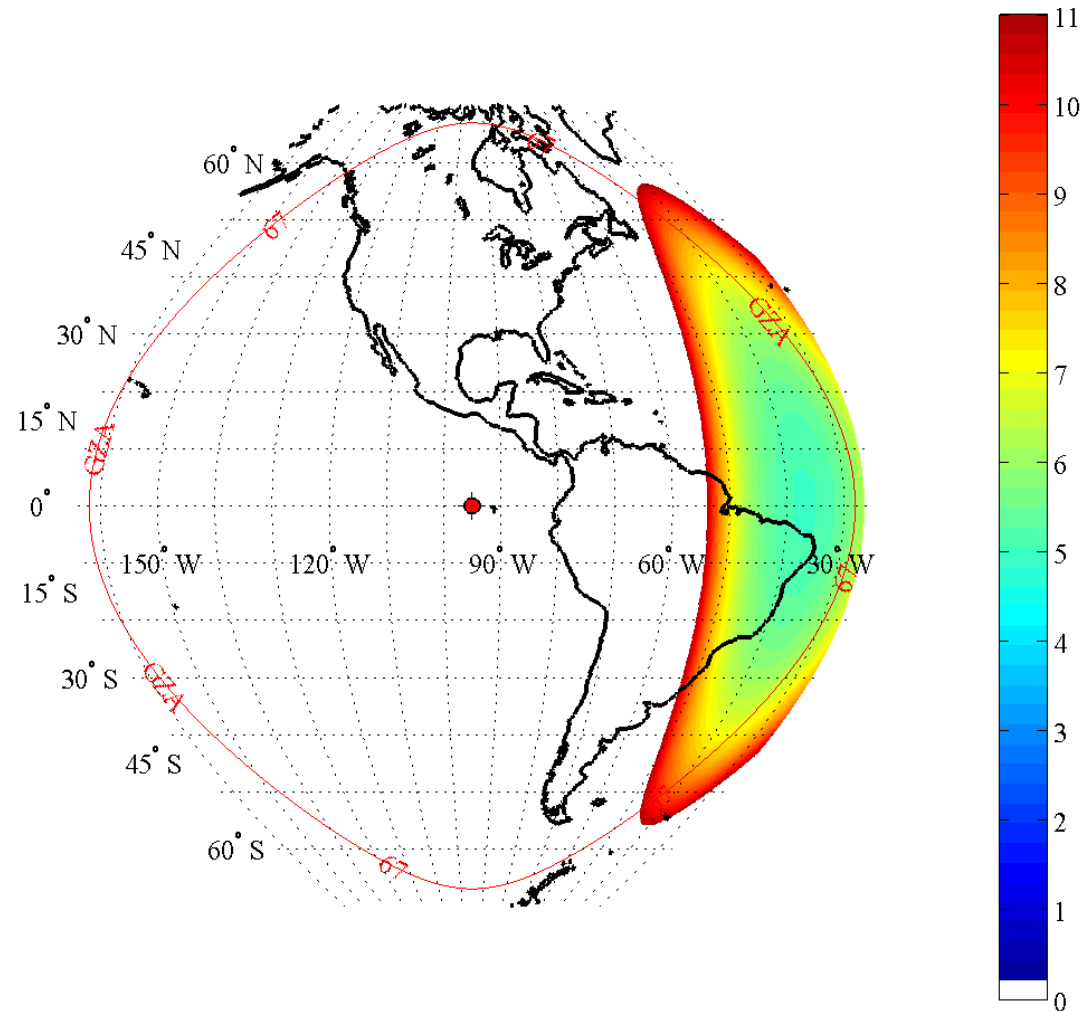
MODIS: 10 detector elements along track for each 1km band; 40 detectors for 250m bands.



# Air Mass Fraction at Equinox for 95°W

Air Mass Fraction @ ST: 21-Sep-2011 04:00:00

- ~16 hours of scan time available each day from ~30°W to ~155° W.
- Scan Atlantic coastal & deep ocean waters in early morning
- Scan Pacific coastal & deep ocean waters in late afternoon

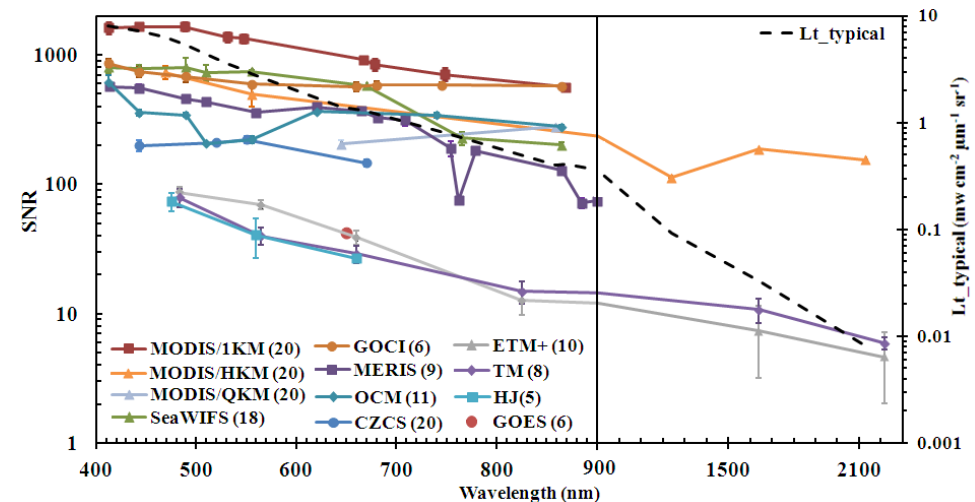


# GEO-CAPE Measurement Requirements: Practical Considerations on Solar Irradiance, Sensitivity, Cloud Cover and Sun Glint

Chuanmin Hu - University of South Florida

## Summary of Activity

- Quantified spectral  $L_{\text{typical}}$  and  $L_{\text{max}}$  under various SZA ( $70^\circ - 0^\circ$ ) using MODIS/Aqua measurements.
- Quantified SNR for several ocean color sensors (MODIS, SeaWiFS, MERIS, CZCS) under identical  $L_{\text{typical}}$  input
- Estimated  $R_{\text{rs}}$  uncertainty induced by using ozone climatology instead of real-time ozone
- Documented signal changes of solar stimulated fluorescence due to efficiency changes at low-light levels
- Provided figures and text to the Geo-CAPE whitepaper (submitted)
- Attended GEO-CAPE workshops and most weekly telecons.



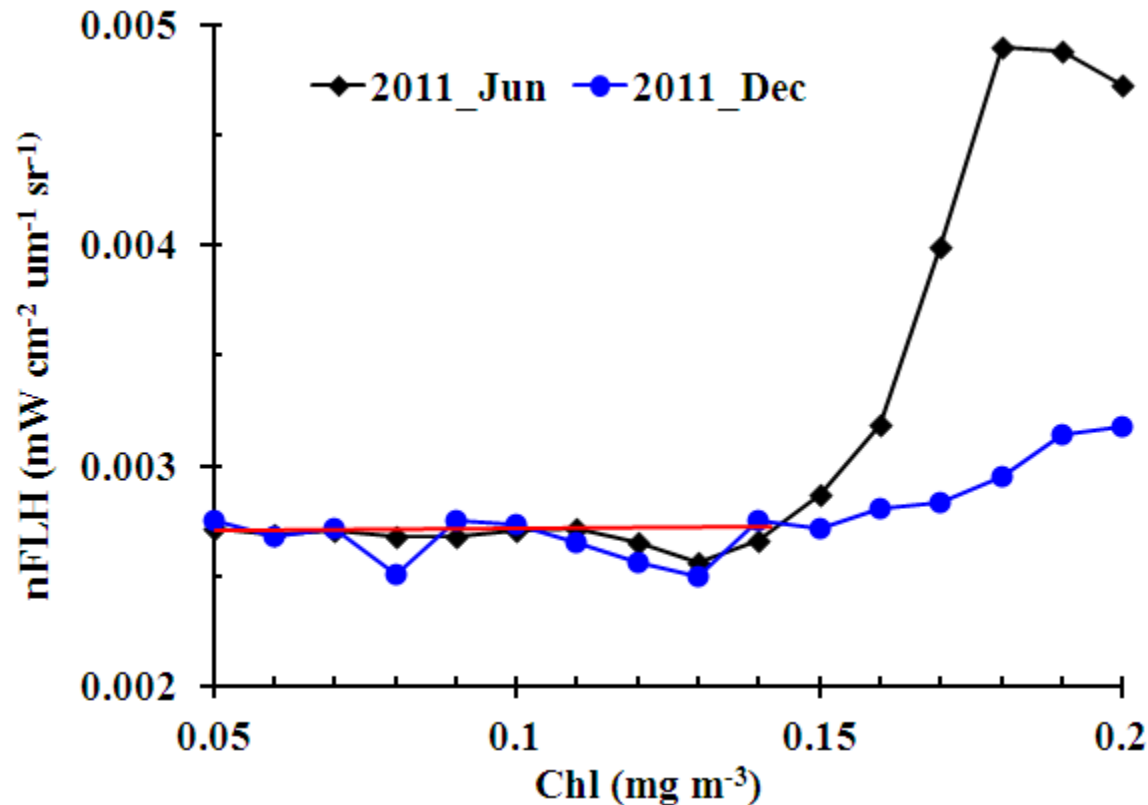
## Impact & recommendations for GEO-CAPE

- $L_{\text{typical}}$  and  $L_{\text{max}}$  estimated from MODIS and extrapolated to other were used for GEO-CAPE sensor specifications
- SNRs from heritage sensors were used as reference to specify GEO-CAPE SNR under given radiance input ( $L_{\text{typical}}$ ).
- Glnt distributions in space and time for GEO-CAPE coverage were obtained. These will be used for mission planning





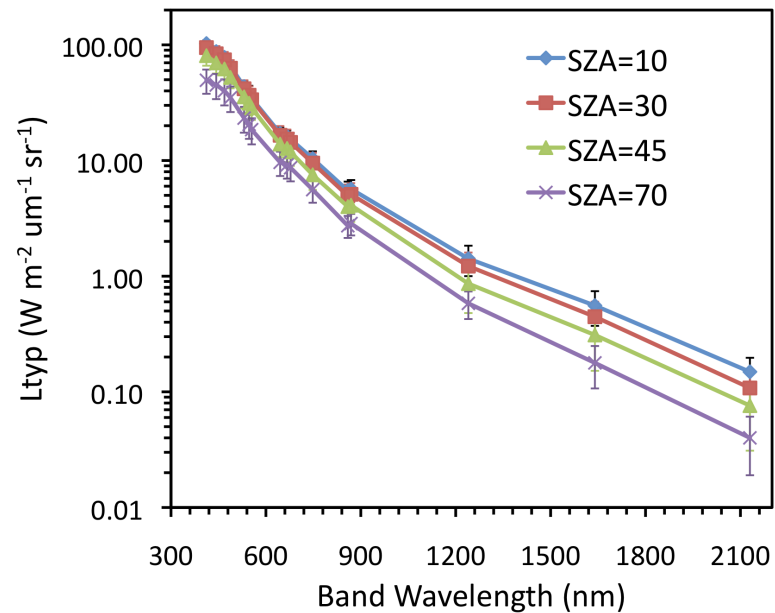
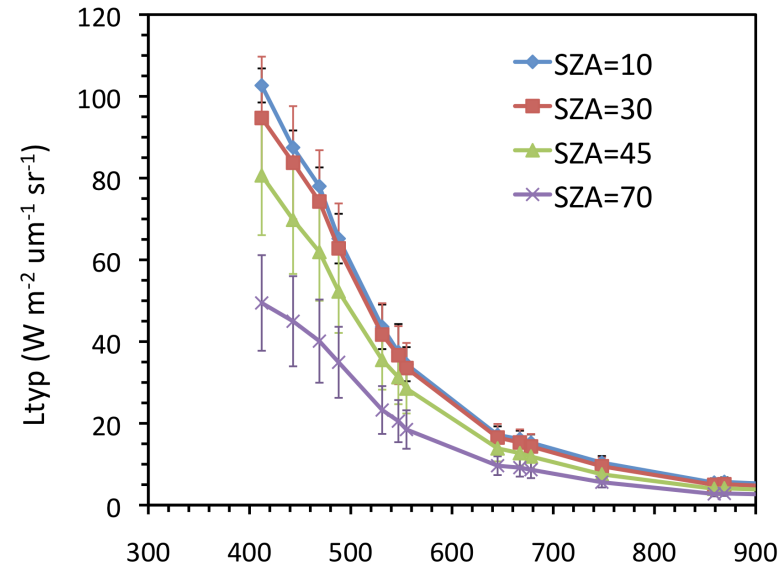
# Sensitivity MODISA FLH



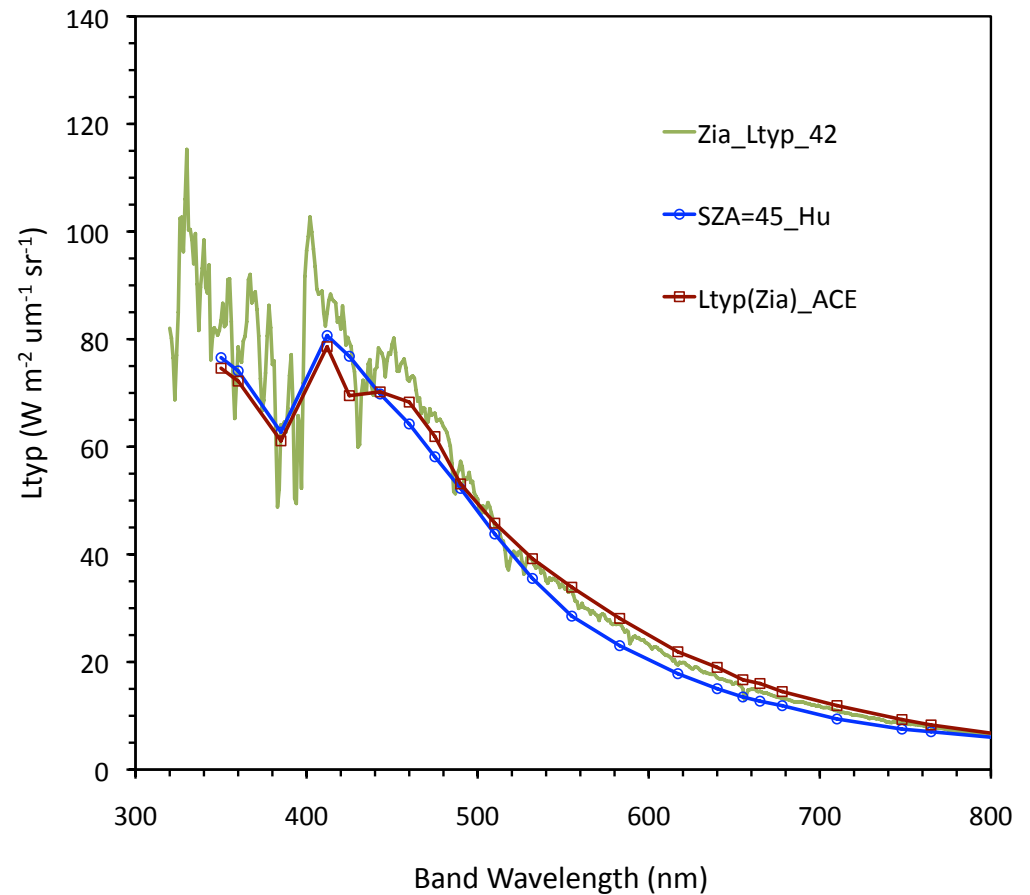
- Sensitivity of MODISA FLH in detecting Chl changes at low concentrations.
- FLH remains stable for Chl < 0.14 – 0.15 mg m<sup>3</sup>, suggesting that FLH is unable to resolve Chl in a local region for low concentrations.
- Data were extracted from a 10° x 10° (60 – 50°W, 30 – 40°N) region near the North Atlantic Gyre, with > 300 (often > 3000) valid pixels used in the calculation for each concentration.



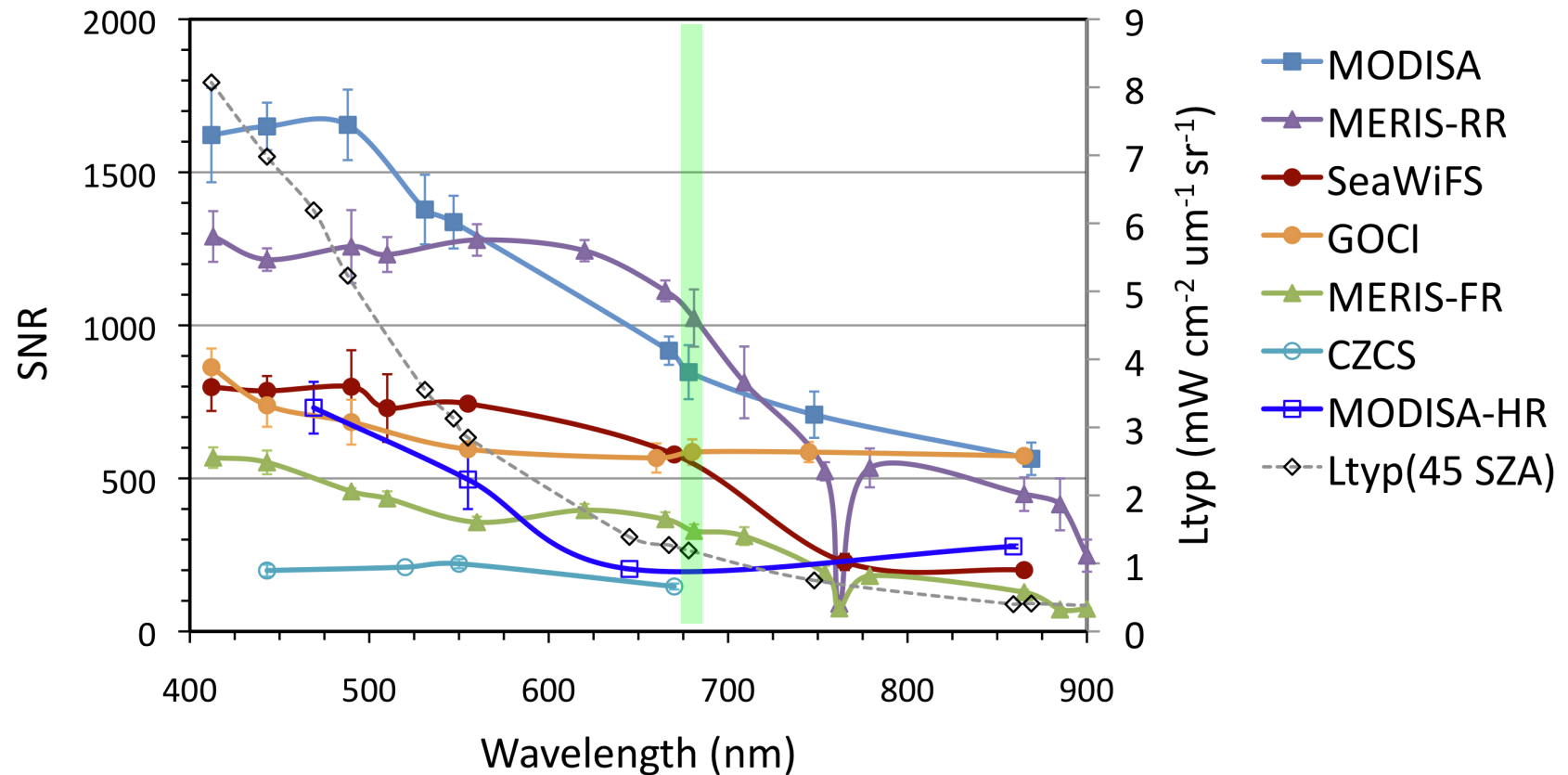
# Sensitivity - Ltyp



GEO-CAPE SNR requirements  
based on  $L_{typ}$  at 70° SZA

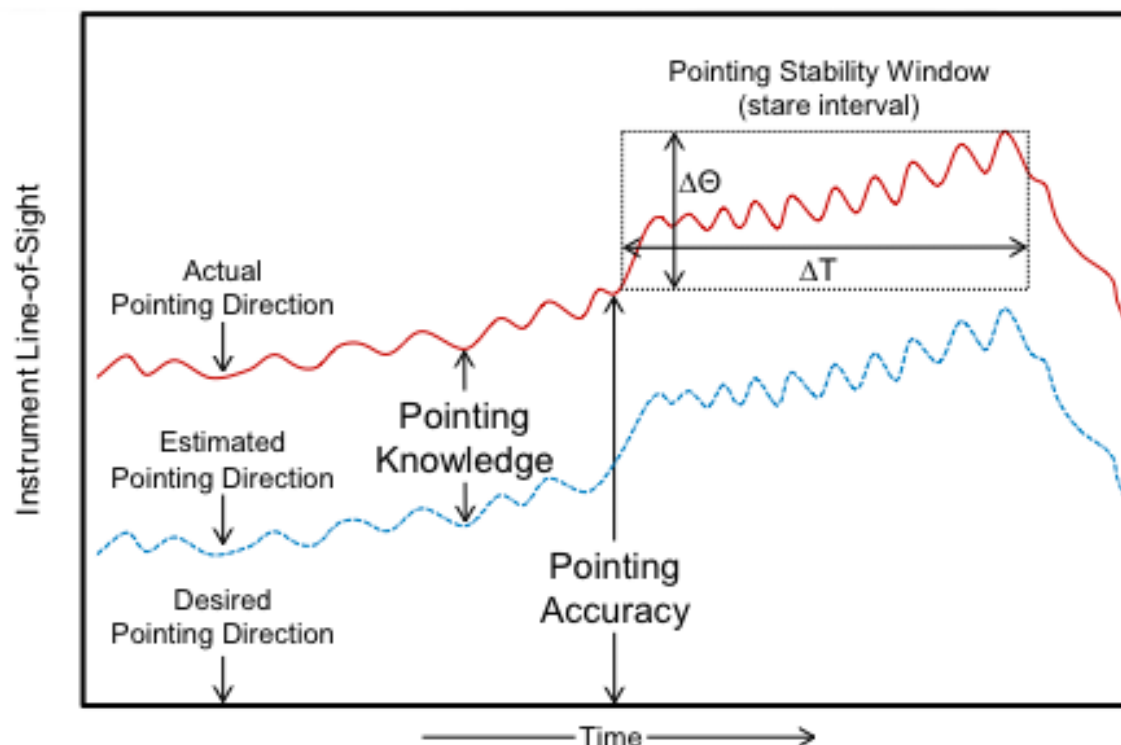


# SNR of Heritage Sensors Scaled to Identical $L_{typ}$ values



# Spatial Resolution & Pointing Requirements

With spatial resolution, must also consider line-of-sight pointing accuracy, knowledge, **stability** and post-processing **geolocation**



- Line-of-Sight Pointing Accuracy: Ability to point a pixel at a specific target location (e.g. a specific latitude / longitude)
- Line-of-Sight Pointing Stability: Ability to keep a pixel pointed to its target during a science observation ( $\Delta\Theta/\Delta T$ )
- Line-of-Sight Pointing Knowledge: Ability to determine a pixel's geo-location after it is pointed to the target (onboard)
- Pointing Geo-Location Reconstruction: Ability to determine the pixel geo-location from the science observation data

# Atmospheric Correction for Oceans - Applications to GEO-CAPE

Jay Herman (UMBC, NASA/GSFC) and Maria Tzortziou (UMCP, NASA/GSFC)

## • Summary of Activity

**Variability in atmospheric aerosols and trace gasses is one of the largest sources of uncertainty for satellite ocean color retrievals, especially in coastal waters that are close to heavily polluted areas.**

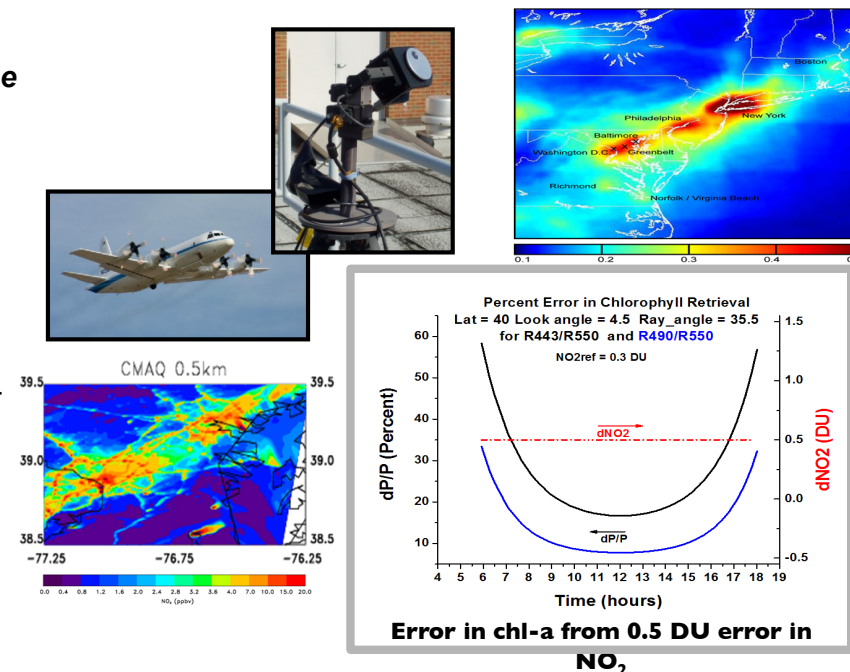
We performed preliminary estimates of the error in remotely-sensed ocean color caused by uncertainties and approximate knowledge of the amount of  $\text{NO}_2$  in the satellite's field of view.

New measurements and regional air-quality model simulations were used to determine spatial and temporal variability in  $\text{NO}_2$  and other trace gases at urban sites close to coastal regions.

Results were assessed in terms of the proposed GEOCAPE OC sensor characteristics and recommendations were made to meet OC retrieval requirements.

## • Results to date

- Measurements at near-coastal land sites show that the temporal variability of  $\text{NO}_2$  can easily exceed 0.5 DU over a period of an hour.
- Considerable temporal variability was also observed in total column  $\text{O}_3$  amounts, as high as 40-50 DU at coastal urban sites.
- The observed short-term temporal changes in  $\text{NO}_2$  and  $\text{O}_3$  amounts cannot be captured by OMI or other satellite instruments in sun-synchronous orbits with at most 1-3 daily overpasses
- Preliminary results suggest that each 0.5 DU change in  $\text{NO}_2$  results in 5-7% error in water leaving radiances at 410 nm, low solar zenith angle ( $< 40^\circ$ ) and low look angle. The error becomes larger (reaching 15-20%) for larger solar zenith and look angles (expected with GEOCAPE), and when  $\text{NO}_2$  is distributed at higher altitude.
- If not sufficiently corrected, such variability in  $\text{NO}_2$  could result in a false temporal variability in chlorophyll-a, with retrievals errors over 50% depending on solar zenith angle.



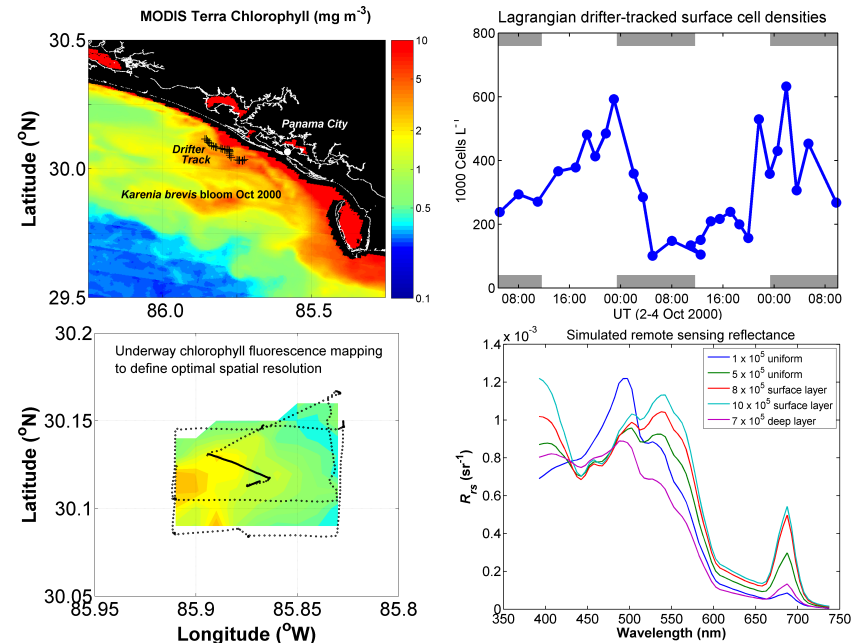
## • Impacts & recommendations for GEO-CAPE

- If uncorrected, atmospheric variability will lead to a false estimate of time-dependent coastal ocean processes.
- The resulting error in  $R_{rs}$  and  $nLw$  is spectrally dependant (with maximum at 400-450 nm), so it does not cancel out when using band-ratios for retrievals of ocean biogeochemical variables.
- Based on these preliminary results, a spectral resolution of 0.8 nm (spectral sampling of 0.4 nm) would be required, at least in the 400-450 nm spectral range, for accurate atmospheric  $\text{NO}_2$  correction of coastal ocean color measurements from GEO-CAPE.
- Additional work, using measurements of atmospheric variability over estuarine and coastal waters and a vector RT code, will provide improved estimates that will be used to assess results in terms of the GEO-CAPE mission objectives and measurement and instrument requirements

# Consideration of Temporal and Spatial Dynamics of Vertically Migrating Harmful Algal Blooms in Support of Developing GEO-CAPE Science and Mission Requirements

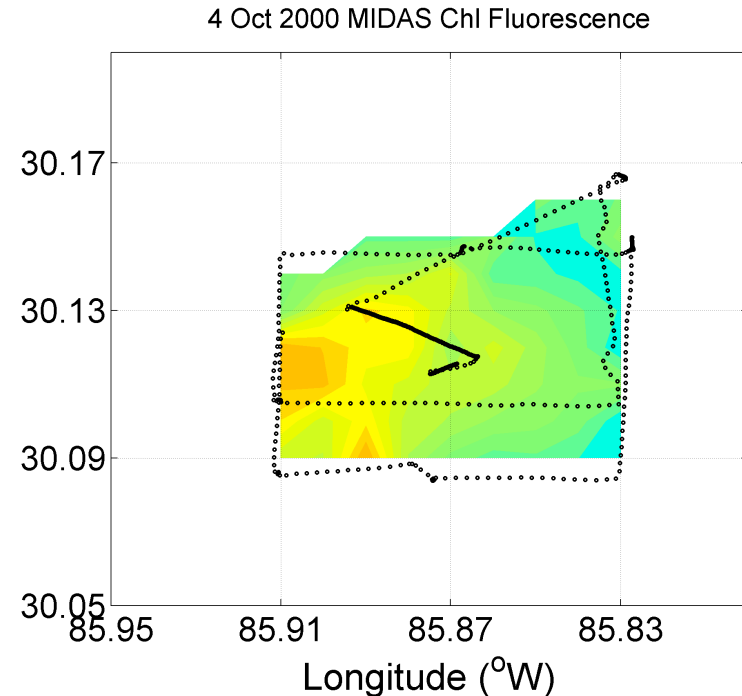
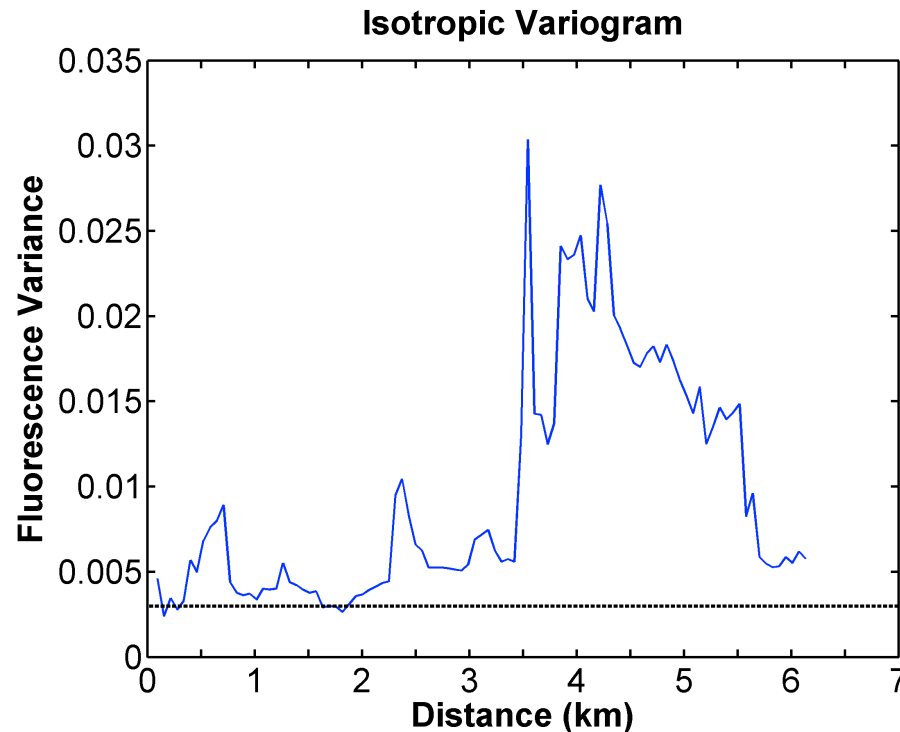
Steven E. Lohrenz - University of Massachusetts Dartmouth

- **Summary:** Systematic analysis of in situ observations to define temporal and spatial scales needed to resolve dynamics and provide diagnostic criteria for discrimination of vertically migrating harmful algal blooms (HABs)
- Objectives:
  - Examine temporal variations in upper water column population distributions and associated inherent optical properties (IOPs) to identify critical temporal sampling scales needed to resolve variations
  - Use radiative transfer modeling in conjunction with measured and modeled IOPs to develop simulated datasets of water leaving radiance in relation to bloom dynamics
  - Examine length scales of bloom features in relation to sensor spatial resolution
- Results to date
  - Temporal variations in HAB vertical migration necessitates acquisition of multiple daily images to resolve and detect
  - Radiative transfer simulations of remote sensing reflectance ( $R_{rs}$ ) for different vertical distributions showed distinct spectral patterns
  - Length scales for underway mapped fluorescence were less than 0.5 km in the vicinity of bloom features



- Recommendations for GEO-CAPE
  - Three to four daily images required to characterize temporal variability in surface bloom dynamics
  - Simulations of  $R_{rs}$  will provide a means to characterize effectiveness of discrimination for different spectral resolutions and vertical bloom distributions
  - **Spatial resolution of <0.5 km is needed to adequately resolve bloom features**

# Spatial Variability Underway Chl-a Fluorescence



Variogram of the residual fluorescence (blue line) compared to the noise threshold (dashed line). Where variance exceeds the noise threshold, this is attributed to real variation in observable patterns.

- Variance in the residuals exceeded the noise level for features having spatial scales on the order of 0.5 km or less.
- Moline et al. (2005) reported minimum length scales of 50-300 m based on spatial scales of optical properties from an autonomous underwater vehicle.
- Bissett et al. (2004) also reported optimal ground sampling scales for inner shelf waters of 50-200 m for locations 1-10 km from shore.



# Spatial Resolution Requirements for GEO-CAPE

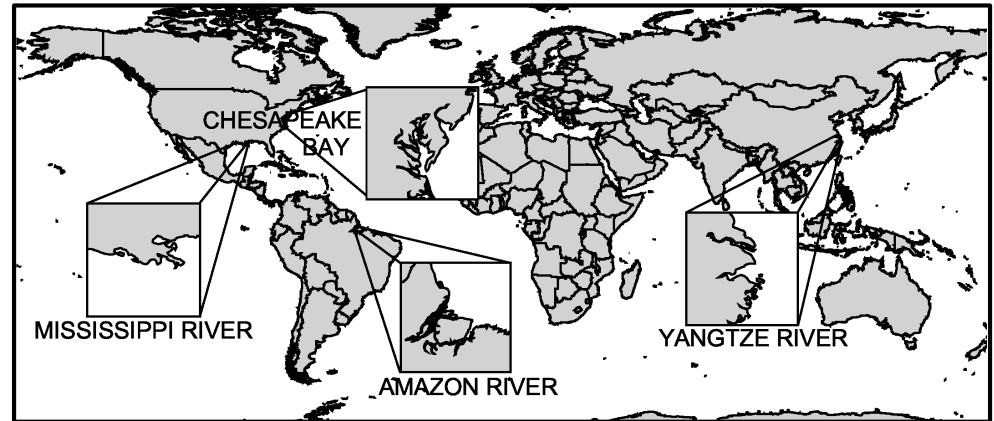
Dirk Aurin & Antonio Mannino – NASA GSFC

## Summary

What resolution best captures spatial structure and dispersion of remotely sensed total suspended materials in coastal and near-shore environments?

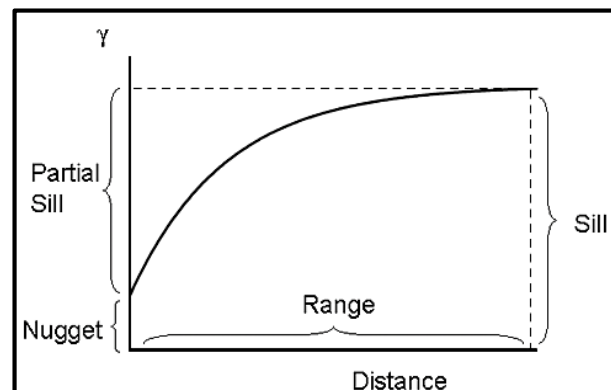
## Approach

- 434 MODIS 250 m resolution images processed to TSM at turbid, optically complex river plumes during peak and nadir flow.
- Interpixel variability,  $\sigma$ , calculated at virtual stations along a transect exiting the plume toward offshore. If  $\sigma$  of an array around each station (i.e. 2x2, 3x3, 4x4 pixels, etc.) exceeds background noise, then heterogeneity in TSM would be missed with coarser resolution.
- Semivariogram analysis to establish degree of variability captured with the plume.



$$\sigma = STD / \bar{p} \quad STD = \left( \frac{1}{n-1} \sum_{i=1}^n (p_i - \bar{p})^2 \right)^{1/2}$$

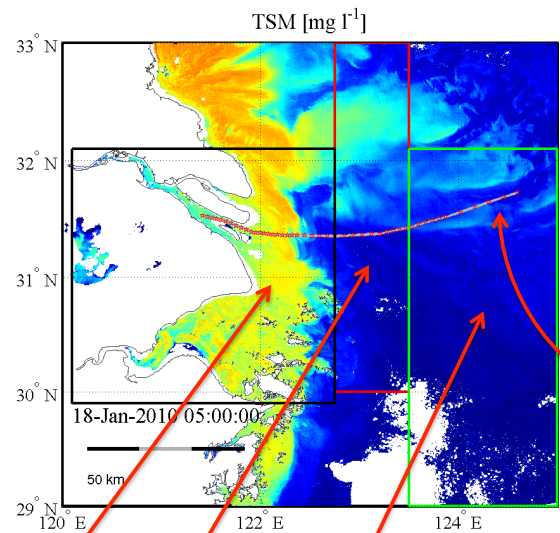
Where  $p_i$  is the property value of the  $i$ th pixel, and  $\bar{p}$  is the average of an array of adjacent pixels



Idealized semivariance  $\gamma(h)$  increases to range as more distant observations diverge, then plateaus at sill. "Nugget" denotes proportion of variance resolved. Slope of  $\gamma(h)$  indicates intermediate scale patchiness.

# Spatial Resolution to Capture TSM Variability in River Plume & Ocean

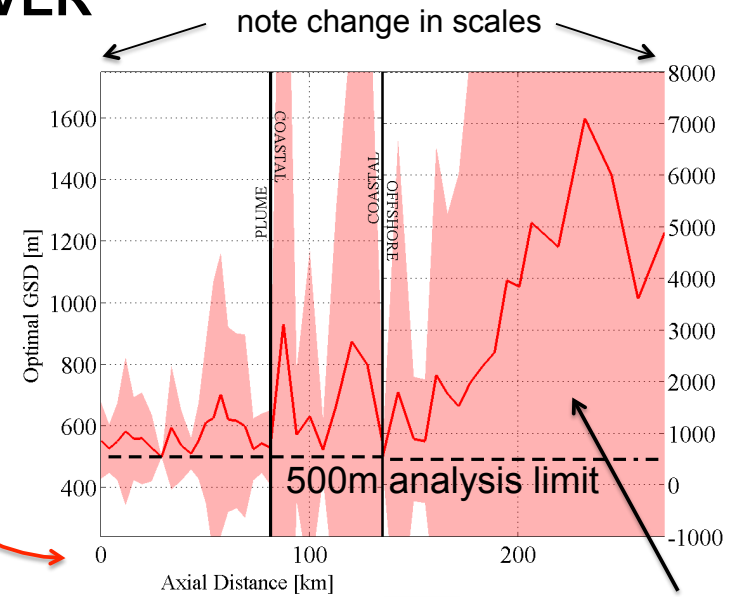
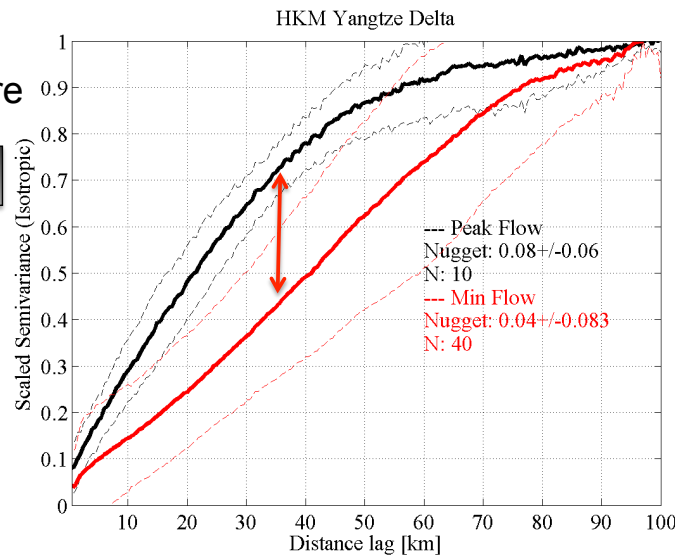
## YANGTZE RIVER



Plume  
Coastal  
Offshore

### Conclusion

- 92% ± 6% variability captured
- Patchiness increases at 20 – 40 km scales during peak flow



Standard error  
(shaded)  
among 84  
images

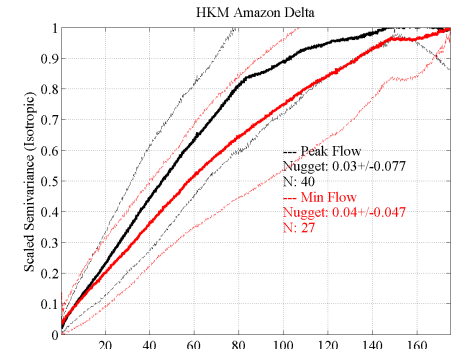
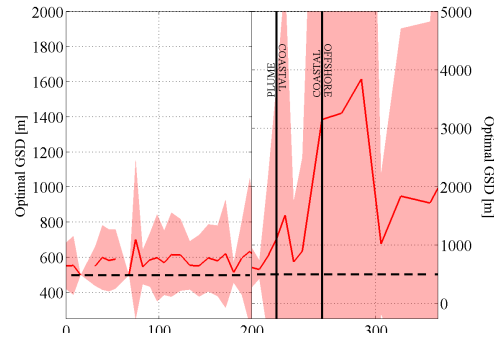
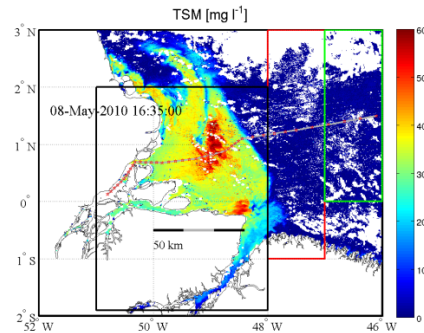
### Conclusion

- ~500m – 600m required in Plume
- ~600m – 800m required Coastal
- ~1km – 6km required Offshore

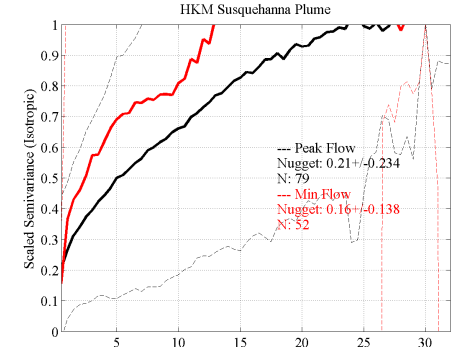
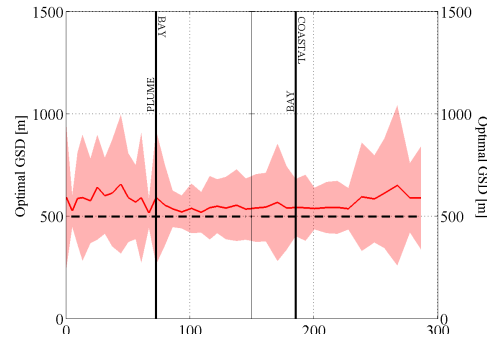
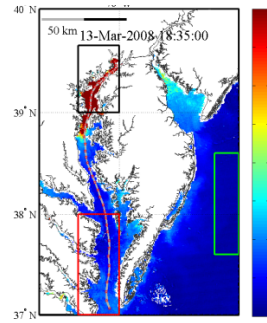


# Spatial Resolution to Capture TSM Variability in River Plume & Ocean

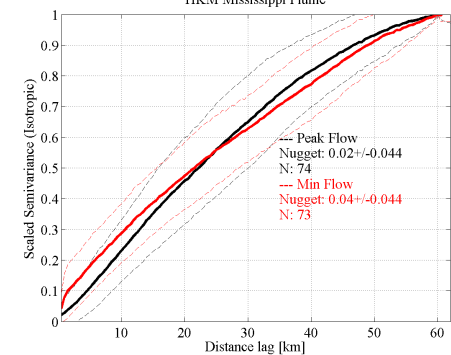
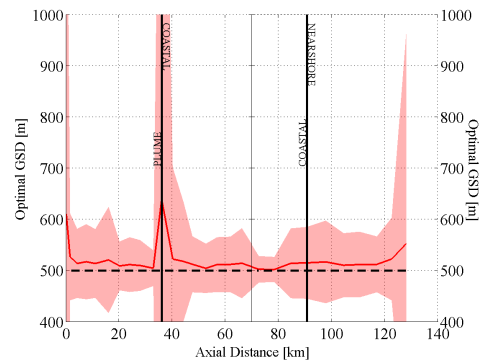
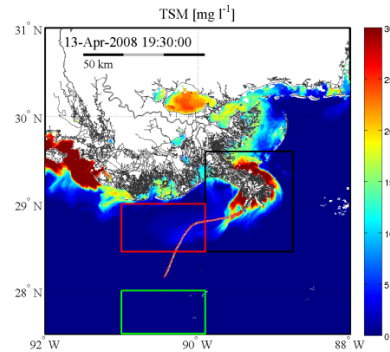
## AMAZON RIVER



## CHESAPEAKE BAY



## MISSISSIPPI RIVER



**500 – 600 m resolution required in all plume and most nearshore regions**

# Tidal exchanges across the land-ocean interface

## Time and space scales of biological, biogeochemical and optical variability

Maria Tzortziou (University of Maryland, NASA/GSFC) and Antonio Mannino (NASA/GSFC)

### • Summary of Activity

Coastal marshes are hot spots of biogeochemical transformation and exchange. ***The time and space scales of these biogeochemical exchanges however, are poorly constrained.***

We conducted high-frequency (hourly), high-resolution (25-100m) field observations to characterize temporal variability in water bio-optical characteristics and spatial gradients in dissolved carbon due to tidal marsh outwelling in the Chesapeake Bay.

***Results were applied to make recommendations on the temporal frequency and spatial resolution required on GEO-CAPE to resolve carbon fluxes, near-shore processes, and exchanges of carbon, nutrients and pollutants at the land-ocean interface.***

### • Results to date

#### Temporal Variability - Summary:

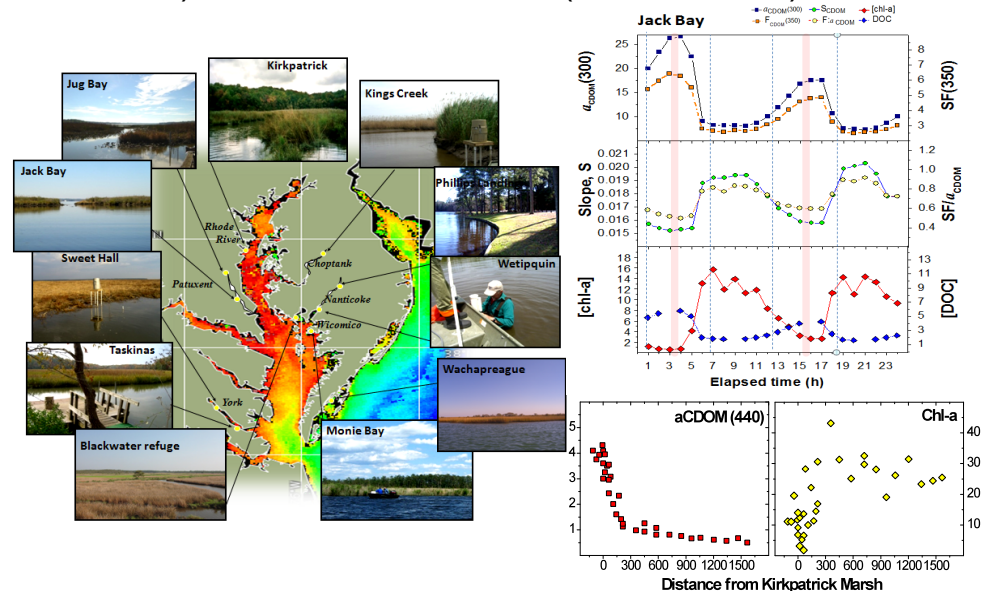
→ Strong temporal variability in biogeochemical variables associated with tidal patterns, ***as strong as by a factor of 15 in chlorophyll, and a factor of 5 in CDOM absorption*** within 6-hour periods (low to high tide).

#### Spatial Variability - Summary:

→ ***Strong spatial gradients in DOC, CDOM, DIC, pCO<sub>2</sub> and chl-a, with changes by a factor of 2 to 10 within a distance of 0.5 to 1 km.***

→ Tidal outwelling of dissolved carbon from wetlands and marshes, and trapping of algae and other suspended particulate matter in marsh systems.

→ Attention is needed when extrapolating observations closer to the “source”, because of non-conservative mixing.



### • Impacts & recommendations for GEO-CAPE

#### Temporal Variability - Resolution:

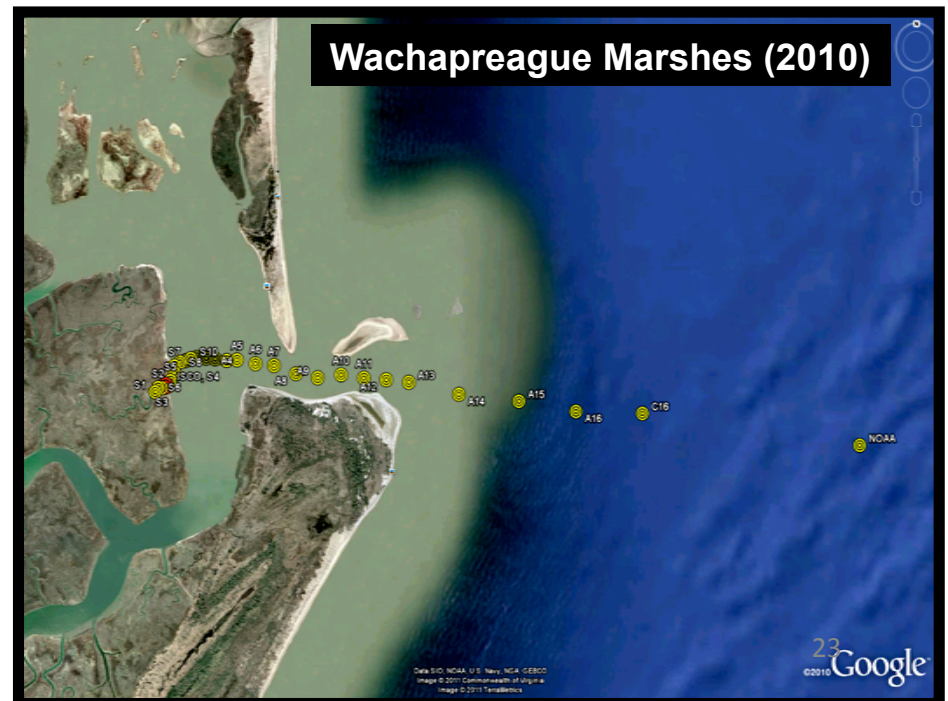
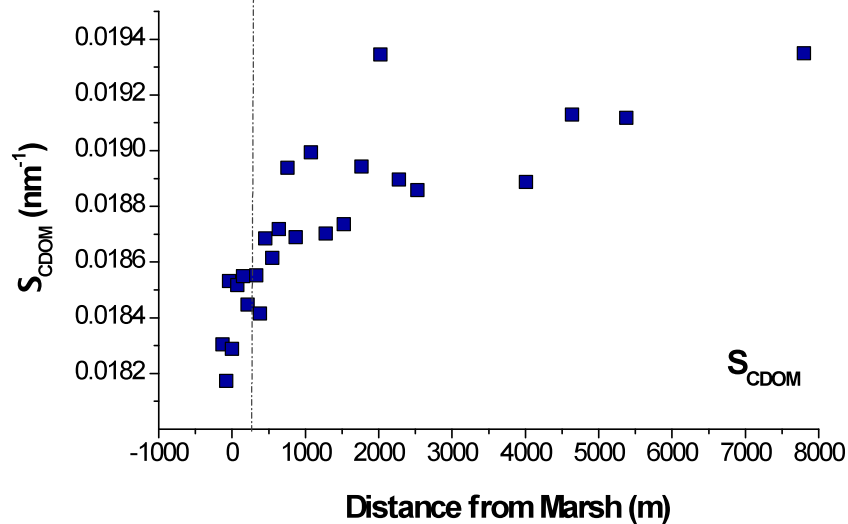
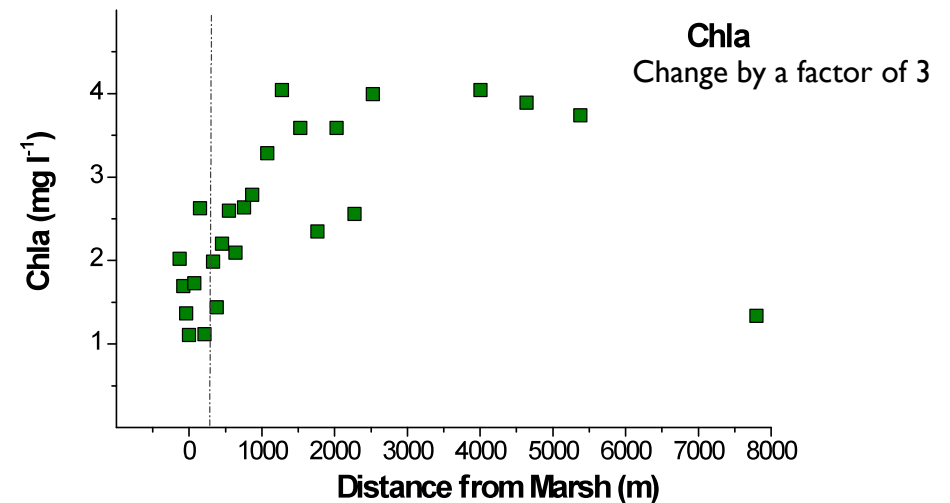
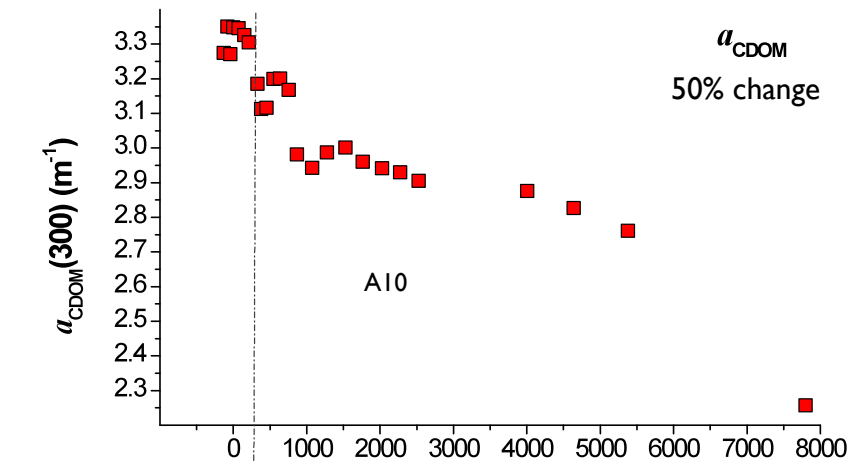
→ ***3-hour resolution is needed to resolve observed patterns.***  
 → Additional information regarding the exact time of low and high tide would improve interpolation and estimates of carbon dynamics and fluxes in estuarine and coastal waters.

#### Spatial Variability - Resolution:

→ ***250-500 m resolution would allow resolving spatial gradients associated with land-ocean exchanges.***  
 → ***1km too coarse to resolve observed biogeochemical gradients.***  
 → ***GEO-CAPE observations will need to be combined with new, advanced estuarine biogeochemical models for assessing the relative importance of different processes at the land-ocean interface.***

Resolution	Needed	Desirable
Temporal	3-hour	1-2 hours
Spatial	500m	250m

# Spatial Scales of biological, biogeochemical and optical variability

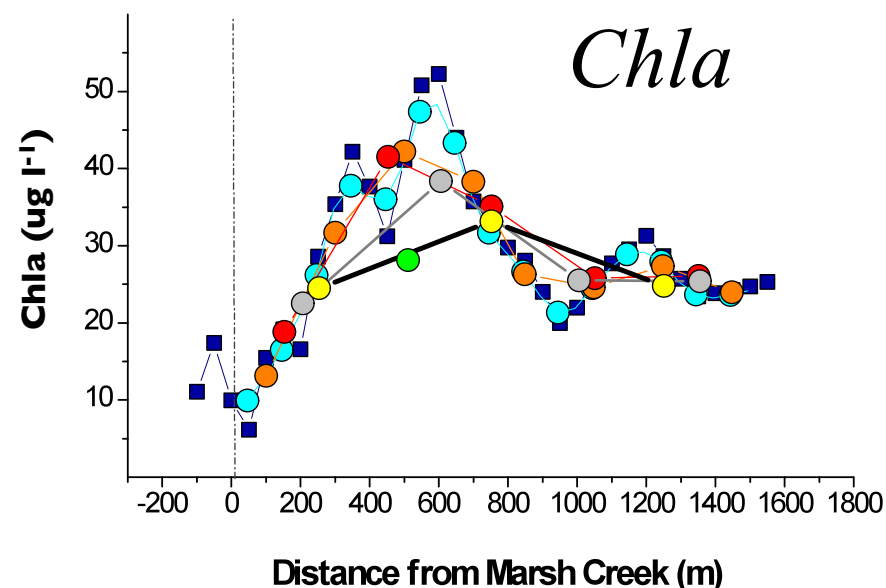
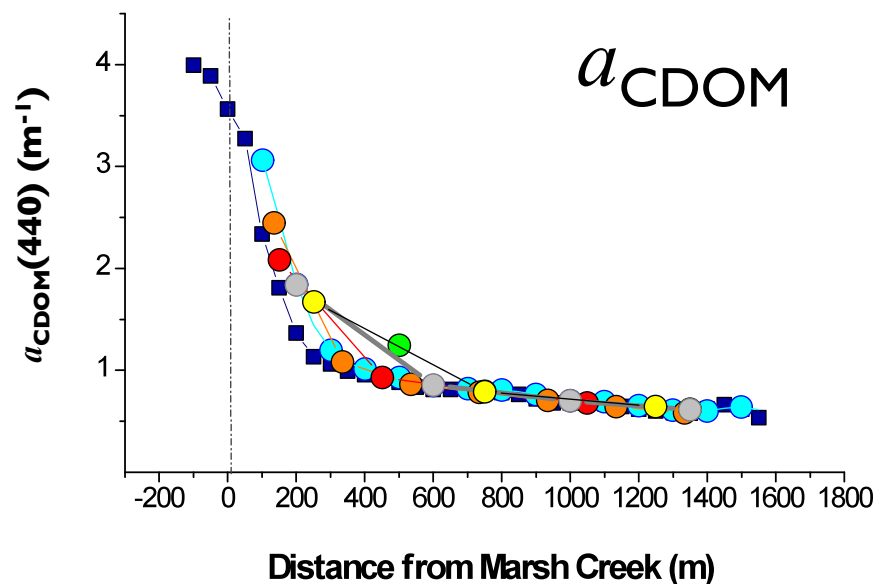


M. Tzortziou, A. Mannino, P. Neale,  
P. Megonigal, M. Butterworth

# Spatial Scales of biological, biogeochemical and optical variability



## Kirkpatrick Marsh



	<u>CDOM</u>	<u>chl-a</u>
100m	± 7%	-10% to 25%
200m	up to 13%	-20% to 40%
300m	up to 25%	-20% to 40%
400m	up to 36%	-25% to 40%
500m	> 40%	-25% to 40%
1 km	> 40%	-40% to 55%

# Spatial Scales of biological, biogeochemical and optical variability



## Spatial Variability - Summary:

- We found strong spatial gradients in DOC, CDOM, DIC,  $p\text{CO}_2$  associated with tidal export of dissolved carbon from marshes
- Marshes seem to trap algae and other suspended particulate matter

## Spatial Variability / Resolution:

- 1km too coarse to resolve these gradients
- 250-500 m resolution would allow resolving spatial gradients associated with land-ocean exchanges
- High resolution is needed to start exploring processes in sub-estuaries & tributaries
- Attention is needed when extrapolating to the “source”, because of non-conservative mixing
- Need combination of satellite observations with field observations and advanced estuarine biogeochemical models to study the land-ocean interface.

## Temporal Variability / Resolution:

- Strong temporal variability in biogeochemical variables associated with tidal patterns, **factor of 15 in chlorophyll, and 5 in CDOM absorption** within 6-hour periods (low to high tide).

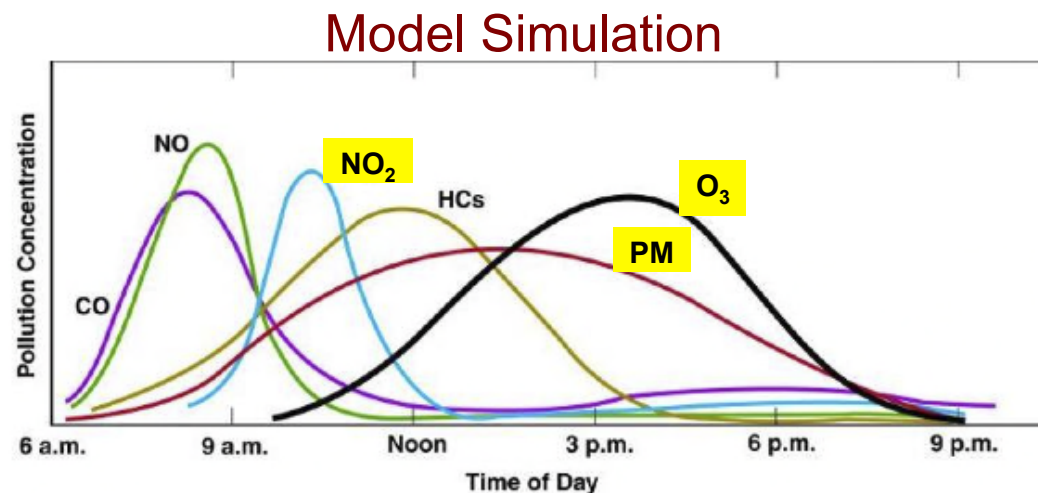
Resolution	Needed	Desirable
<b>Temporal</b>	<b>3-hour</b>	<b>1-2 hours</b>
<b>Spatial</b>	<b>500 m</b>	<b>250 m</b>



# Synthesis of Science Study Recommendations on Requirements



- **Temporal resolution:** <3 hour frequency needed; <1-2 hour desirable
- **Spatial resolution:** <500 x 500m (local) needed; 250 x 250m desirable
- If uncorrected, atmospheric variability (aerosols, NO<sub>2</sub>, O<sub>3</sub>, etc.) will lead to a false estimate of time-dependent underwater processes in coastal areas.
- **Spectral resolution** of 0.8 nm (spectral sampling of 0.4 nm) would be required, at least in the 400-450 nm spectral range, for NO<sub>2</sub> correction.



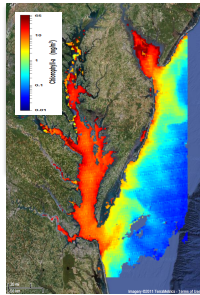
**Tropospheric chemistry evolves rapidly during the day**

# Potential Synergies of PACE & GEO-CAPE

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- Infrastructure: vicarious calibration sites, ground station resources, *in situ* sensor technology development, augmenting AERONET sites, airborne sensors, etc.
- Joint field campaigns – pre- and post-launch
  - Algorithm development (UV, hyperspectral, etc.)
  - Atmospheric corrections
- Use PACE for data at high latitudes beyond GEO-CAPE FOR
- Use PACE as proxy data to learn how to handle hyperspectral data sets
- cal/val plan: vicarious calibration site within GEO-CAPE OC FOR but not too steep sensor angle.
- Cross-calibration/validation of satellite sensors
- GEO-CAPE support for open ocean experiments

<http://geo-cape.larc.nasa.gov>



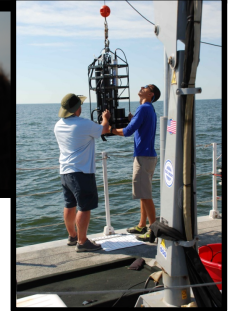
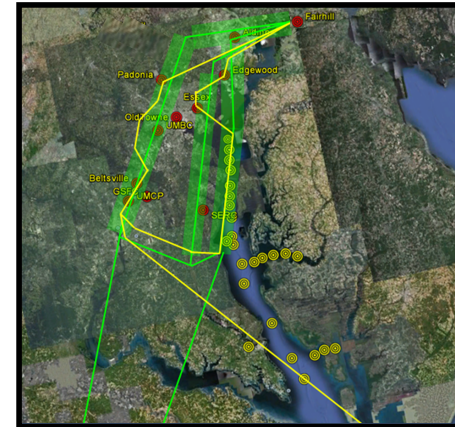
# GEO-CAPE July 2011 field campaign in Chesapeake Bay (CBODAQ)



## Summary of Activity

Goal was to obtain detailed atmospheric & oceanographic observations for characterizing short-term dynamics and spatio-temporal variability in atmospheric and coastal ecosystem processes.

- 1) **Transects** – sampling along a gradient (north to south, river tributary to open waters of the bay, salt marsh creek to open waters of bay),
- 2) **Sampling a water mass** throughout a day by following a surface drifter, and
- 3) **Sampling same location** throughout a day



## Measurements

- High resolution (spatial, temporal and spectral) UV-Vis-NIR multi-/hyperspectral AOPs, IOPs, POC/PN, DOC, SPM, nutrients, primary production, CTD, aerosol spectral properties & composition, column & surface trace gases (ozone, NO<sub>2</sub>), boundary layer height, meteorological data.
- Measurements coordinated with DISCOVER-AQ aircraft flights over Chesapeake Bay.

<http://geo-cape.gsfc.nasa.gov/>

Results will lead to recommendations on

- measurement requirements,
- instrument requirements,
- atmospheric correction,
- interdisciplinary science,
- algorithm development for coastal products.



# Constellation of Ocean Color Science Missions

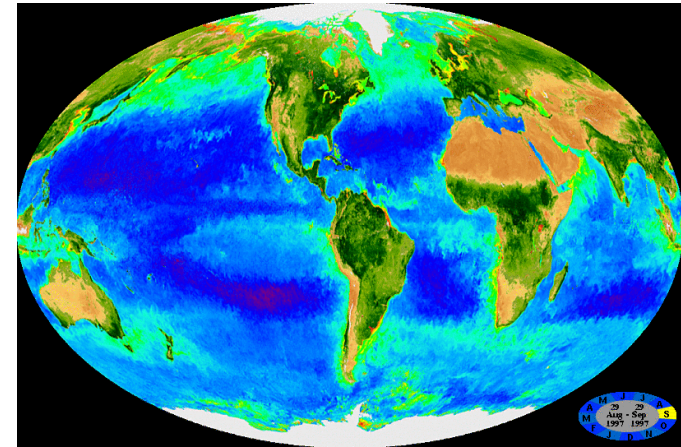
## Global ocean color missions:

- JAXA S-GLI; ESA OLCI; etc.
- NASA PACE (2019); ACE (>2020)

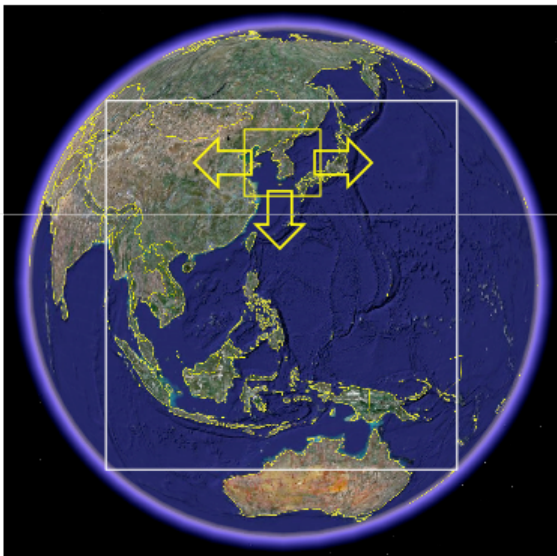
## Geo ocean color missions:

- Korea's GOCI-II
- NASA's GEO-CAPE
- ESA's HOCI or OCAPI
- ISRO's HR-Geo

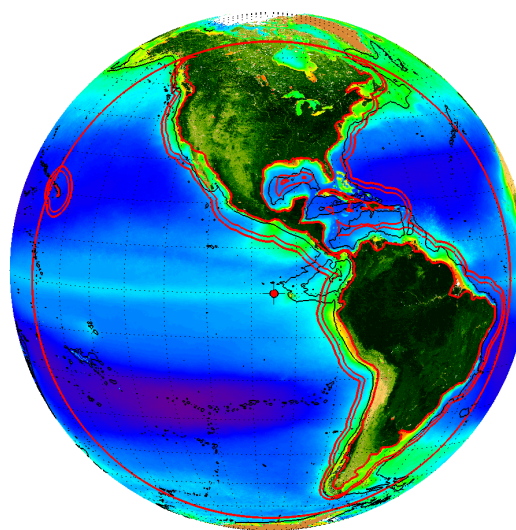
PACE-OES, OLCI, S-GLI, etc.



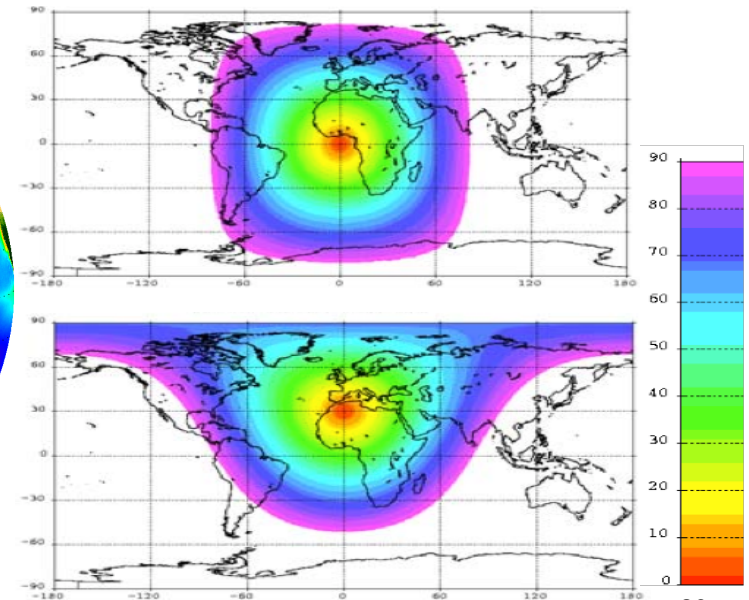
GOCI-II: 2018



GEO-CAPE: >2020



OCAPI: ?



# Backup



# GEO-CAPE Oceans STM

Draft v.4.0 - Dec. 8, 2011

Science Focus	Science Questions	Approach	Measurement Requirements	Instrument Requirements	Platform Requirements	Ancillary Data Requirements															
Short-Term Processes  Land-Ocean Exchange  Impacts of Climate Change & Human Activity  Impacts of Airborne-Derived Fluxes  Episodic Events & Hazards	<b>1</b> How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics? (OBB 1)	GEO-CAPE will observe coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, and track carbon pools and pollutants. Two complementary operational modes will be employed: (1) survey mode for evaluation of diurnal to interannual variability of constituents, rate measurements and hazards for estuarine and continental shelf and slope regions with linkages to open-ocean processes at appropriate spatial scales, and (2) targeted, high-frequency sampling for observing episodic events including evaluating the effects of diurnal variability on upper ocean constituents, assessing the rates of biological processes and coastal hazards. <i>Measurement objectives for both modes include:</i> (a) Quantify dissolved and particulate carbon pools and related rate measurements such as export production, air-sea CO <sub>2</sub> exchange, net community production, respiration, and photochemical oxidation of dissolved organic matter. (b) Quantify phytoplankton properties: biomass, pigments, functional groups (size/taxonomy/Harmful Algal Blooms (HABs)), daily primary productivity using bio-optical models, vertical migration, and chlorophyll fluorescence. (c) Measure the inherent optical properties of coastal ecosystems: absorption and scattering of particles phytoplankton and detritus, CDOM absorption. (d) Estimate upper ocean particle characteristics including particle abundance and particle size distribution. (e) Detect, quantify and track hazards including HABs and petroleum-derived hydrocarbons.	Water-leaving radiances in the near-UV, visible & NIR for separating absorbing & scattering constituents & chlorophyll fluorescence  Product uncertainty TBD  <b>Temporal Resolution:</b> <i>Targeted Events:</i> • Threshold: ≤1 hour • Baseline: ≤0.5 hour <i>Survey Coastal U.S.:</i> • Threshold: ≤3 hours • Baseline: ≤1 hour <i>Regions of Special Interest (RSI):</i> Threshold: ≥1 RSI 3 scans/day • Baseline: multiple RSI 3 scans/day <i>Other coastal and large inland bodies of water within ocean color FOR:</i> • Threshold: ≥4 times/yr • Baseline: ≤3 hours  <b>Spatial Resol. (nadir):</b> • Desclope: ≤500 x 500 m • Threshold: ≤375 x 375 m • Baseline: ≤250 x 250 m  <b>Field of Regard for Ocean Color Retrievals:</b> 60°N to 60°S; 155°W to 35°W  <b>Coastal Coverage:</b> width from coast to ocean: • Threshold: min 375 km • Baseline: min 500 km  RSI examples: Amazon & Orinoco River plumes, Peruvian upwelling, Cariaco Basin, Bay of Fundy, Rio Plata, etc. TBD)	<b>Spectral Range:</b> Hyperspectral UV-VIS-NIR • #Threshold: 345-1050 nm; 2 SWIR bands 1245 & 1640 nm • Baseline: 340-1100 nm; 3 SWIR bands 1245, 1640, 2135 nm  <b>Spectral Sampling &amp; Resolution:</b> • Threshold: UV-Vis-NIR: ≤2 & ≤5nm; 400-450nm: ≤0.4 & ≤0.8nm (NO <sub>2</sub> )#; SWIR resolution: ≤20-40 nm • Baseline: UV-Vis-NIR: ≤0.25 & 0.75 nm; SWIR: ≤20-50 nm  <b>Signal-to-Noise Ratio (SNR) at Ltp(70° SZA):</b> • Threshold: ≥1000:1 for 10 nm FWHM (350-800 nm); ≥600:1 for 40 nm FWHM in NIR; ≥250:1, ≥180:1 and ≥100:1 for the 1245 & 1640 nm (20 & 40 nm FWHM); ≥500:1 NO <sub>2</sub> band. • #Baseline: ≥1500:1 for 10 nm (350-800 nm); NIR, SWIR and NO <sub>2</sub> bands same as threshold; ≥100:1 for the 2135nm (50nm FWHM)  <b>Scanning area per unit time:</b> Threshold: ≥25,000 km <sup>2</sup> /min; Baseline: ≥50,000 km <sup>2</sup> /min  <b>Field of Regard:</b> • Full disk: 20.8° E-W and 19° N-S imaging capability from nadir for Lunar & Solar Calibrations  <table><tr><th>#Error (as % of nadir pixel)</th><th>Threshold</th><th>Baseline</th></tr><tr><td><b>Pointing Knowledge LOS</b></td><td>&lt;50%</td><td>&lt;10%</td></tr><tr><td><b>Pointing Accuracy LOS</b></td><td>&lt;100%</td><td>&lt;25%</td></tr><tr><td><b>Pointing Stability LOS</b></td><td>&lt;50%</td><td>&lt;10%</td></tr><tr><td><b>Geolocation Reconstr.</b></td><td>#&lt;100%</td><td>&lt;10%</td></tr></table> <b>Non-saturating detector array(s) at Lmax</b>  <b>On-board Calibration:</b> • Lunar: Threshold: minimum monthly; Baseline: same as threshold • Solar: Threshold: none; Baseline: daily  <b>Polarization Sensitivity:</b> <1.0%  <b>Relative Radiometric Precision:</b> • Threshold: ≤1% through mission lifetime • Baseline: ≤0.5% through mission lifetime  <b>Mission lifetime:</b> Threshold: 3 years; Goal: 5 years	#Error (as % of nadir pixel)	Threshold	Baseline	<b>Pointing Knowledge LOS</b>	<50%	<10%	<b>Pointing Accuracy LOS</b>	<100%	<25%	<b>Pointing Stability LOS</b>	<50%	<10%	<b>Geolocation Reconstr.</b>	#<100%	<10%	Geostationary orbit at 95W longitude to permit sub-hourly observations of coastal waters adjacent to the continental U.S., North, Central and South America  Storage and download of full spatial data and spectral data.	Western hemisphere data sets from models, missions, or field observations  <b>Measurement Requirements</b> (1) Ozone (2) Total water vapor (3) Surface wind velocity (4) Surface barometric pressure (5) Vicarious calibration & validation - coastal (6) Full plume characterization (7) Cloud cover  <b>Science Requirements</b> (1) SST (2) SSH (3) PAR (4) UV solar irradiance (5) MLD (6) AirSea pCO <sub>2</sub> (7) pH (8) Ocean circulation (9) Tidal & other coastal currents (10) Aerosol & dust deposition (11) run-off loading in coastal zone (12) Wet deposition in coastal zone (13) Wave height & surface wind speed  <b>Validation Requirements</b> Conduct high frequency field measurements and modeling to validate GEO-CAPE retrievals from river mouths to beyond the edge of the continental margin.
	#Error (as % of nadir pixel)	Threshold	Baseline																		
	<b>Pointing Knowledge LOS</b>	<50%	<10%																		
	<b>Pointing Accuracy LOS</b>	<100%	<25%																		
	<b>Pointing Stability LOS</b>	<50%	<10%																		
<b>Geolocation Reconstr.</b>	#<100%	<10%																			
<b>2</b> How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics? (OBB 1 & 2)																					
<b>3</b> How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability? (OBB 1, 2 & 3)																					
<b>4</b> How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes significantly affect the ecology and biogeochemistry of coastal and open ocean ecosystems? (OBB 1 & 2)																					
<b>5</b> How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone? (OBB 4)																					

GEO-CAPE Science Questions are traceable to NASA's OBB Advanced Planning Document ....

\* Coastal coverage within field-of-view (FOV) includes major estuaries and rivers such as Chesapeake Bay & Lake Pontchartrain/Mississippi River delta, e.g., the Chesapeake Bay coverage region would span west to east from Washington D.C. to several hundred kilometers offshore (total width of 375 km threshold).

# Requirements under review for further discussion



# Ocean Color Products

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## **Mission Critical Products** (drive requirements; heritage algorithms)

- **Spectral remote sensing reflectances -  $R_{rs}$**
- Chlorophyll-a, Primary Productivity
- Particulate Organic Carbon, Dissolved Organic Carbon, Particulate Inorganic Carbon (coccolithophore blooms)
- Total Suspended Matter
- Absorption coefficients of Colored Dissolved Organic Matter, Particles & Phytoplankton; Particle backscatter coefficient
- Water clarity ( $k_d[490nm]$ ; euphotic depth)
- Photosynthetically Available Radiation
- Fluorescence Line Height, Phytoplankton Carbon
- Functional/taxonomic group distributions
- Harmful Algal Bloom detection & magnitude
- *Aerosols,  $NO_2$  & other products for atmospheric corrections*

## **Highly Desirable Products** (experimental products)

- Particle size distributions & composition, other plant pigments, phytoplankton physiological properties, vertical migration detection
- Net Community Production, Export Production, Respiration, Photooxidation
- Air Sea  $CO_2$  fluxes,  $pCO_2(aq)$
- Terrigenous Dissolved Organic Carbon
- Petroleum detection and thickness

# GSD Resolution = 375m (nadir – 95W) near Vancouver (25km<sup>2</sup> averages)

